Noll, C. F et al

BULLETIN 315 MAY, 1935

FIELD EXPERIMENTS WITH PHOSPHATES

EFFECT OF FERTILIZERS ON WHEAT
Left: No Fertilizer; Right: Phosphoric Acid and Potash

THE PENNSYLVANIA STATE COLLEGE
SCHOOL OF AGRICULTURE AND EXPERIMENT STATION
STATE COLLEGE, PENNSYLVANIA

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Field Experiments With Phosphates

C. F. Noll, C. J. Irvin, and F. D. Gardner.

THE PRIMARY object of this fertilizer test was to compare the most commonly used sources of phosphoric acid, and to compare different rates of application of 16 per cent superphosphate and of rock phosphate. Incidentally, it was planned to discover the value of nitrate of soda when added to superphosphate and muriate of potash, the relative value of different amounts of muriate of potash, the effects of adding gypsum and flour of sulphur to rock phosphate, and to compare two methods of applying superphosphate and rock phosphate. This experiment supplements the Jordan Soil Fertility Plots, which were begun in 1881. A summary of the results on these plots for 50 years is given in Bulletin 264.

Plan. The area comprises 164 one-tenth acre plots in 4 tiers of 41 plots each, located at State College on Hagerstown silt loam, a sedentary soil of limestone origin. The plots are separated by 3-foot strips of blue grass sod. They were laid out in 1916.

Four crops are grown in rotation—corn, oats, wheat, and mixed clover and timothy. Each crop occupies the land one year, in the order given; there being four tiers, all crops are grown every year. Except on the check plots, the treatments are not repeated in a tier, but there are four repetitions in the four tiers.

Lime was applied at the beginning of the experiment on each tier at approximately the amount needed to meet the lime requirements of the most acid plots; four plots, however, received no lime. More lime has been applied when it has seemed to be needed to maintain good yields of clover. These applications, except on tier I in 1926, have been varied to meet the theoretical lime requirements on the different plots. Lime has been applied in the form of ground limestone, 18-20 mesh, or finer.

Fertilizers Used.—Manure and commercial fertilizers are applied to corn and wheat; the other two crops receive no fertilizer directly. Manure is applied before plowing, also rock phosphate except on plot 28. The other commercial fertilizers, except superphosphate on plot 27, are applied broadcast on the plots shortly before seeding, and harrowed in.

Manure is applied at a uniform rate of six tons per acre except on plot 34, where the rate after the first rotation has been varied according to the crops produced. The manure usually was obtained from the dairy barn, where shavings or saw dust made up a large part of the litter. Each application has been analyzed; the average plant food elements per ton were approximately 12 pounds of nitrogen, 5 pounds of phosphoric acid, and 9 pounds of potash. On plot 34 an attempt is made to return to the field as much manure as would be produced on a livestock farm where all of the crops were used on the farm except the wheat grain. The rate for the first rotation was 6 tons per application; thereafter, approximately 5 tons, this being 1¼ tons

to each ton of crops produced in the preceding rotation exclusive of wheat grain.

The rock phosphate used until the spring application in 1928 was that which had been ground for making superphosphate. Thereafter, a more finely ground phosphate, intended for direct use, has been applied. There is no evidence that the more finely ground rock phosphate is more efficient (Table 9).

Variation in Plots.—The area on which the plots were laid out, in 1916, was part of a depleted tenant farm purchased by The Pennsylvania State College in 1914. The plots are located on what had been five fields; four of these were farmed by the College in 1915 and moderately fertilized, and two were limed. In order to determine the variation in the plots at the beginning of the experiment, they were all cropped through one rotation without fertilizer. and the yields recorded. These preliminary results have not been used in interpreting results. A few abnormally high or low yields after the treatments began probably can be explained by the previous history of the plots concerned, but it appears that much of the variability was only temporary. The check plots, which occur every fifth place and receive phosphoric acid and potash, have been less variable under uniform treatment than they were in the preliminary period, and have become more uniform as the experiment has progressed. The plots varied on total yield before fertilization began from 12 per cent below the average to 24 per cent above; but in the 12 years with fertilization only from 8 per cent below to 8 per cent above.[1]

Beginning with plot 1, every fifth plot is a check; it receives phosphoric acid and potash. Where the yield on one check differs from that of the next it is assumed that there is a gradual change in productivity. An attempt is made to correct for these differences by applying the method given in Bulletins 108 and 252.

Prices.—It is difficult to state with any great degree of accuracy the profits derived from a fertilizer treatment, even for a given soil, because of great fluctuations in prices of farm crops and fertilizers, and variations in yields; yet whether a fertilizer treatment can be recommended depends upon the probability of realizing a net return. The prices of crops, as used in this publication, are the average Pennsylvania prices for corn, oats, and wheat grain on December 1; for hay, about eight per cent less than the average price, to allow for shrinkage. The corn yields are based on 14 per cent moisture (allowed in No. 2 grade). Straw and stover are computed at $5 per ton.

The prices for fertilizers are approximately what these materials could be bought for in the quantity needed on a farm of moderate size. Basic slag and rock phosphate are not regularly sold in Pennsylvania; hence there is no established market price. Manure is given an arbitrary value of $1.50 per ton. The prices used were:

Corn ears, per bu. 70 lbs.	$ .75
Corn stover, per ton	5.00

[1] The coefficient of variability of these plots for the total yields of all crops in the rotation before fertilization was 11.49 ± 1.85 per cent and for the three rotations after fertilization 4.37 ± .69.

TABLE 1. A COMPARISON OF RETURNS FROM ALL TREATMENTS, AVERAGES FOR THREE ROTATIONS, 1922-1933

Treatments	Average yields per acre								Sum of annual acre yields of crops Lbs.	Costs of fertilizers in a rotation	Value of all crops in a rotation	Value of all crops in a rotation less cost of fertilizers
	Plot Nos.	Corn grain Bu.	Corn stover Lbs.	Oats grain Bu.	Oats straw Lbs.	Wheat grain Bu.	Wheat straw Lbs.	Hay Lbs.				
L.	20, 40	26.0	1531	30.2	810	8.7	786	1349	7,759	----------	$57.70	$57.70
L, N–K	10	26.0	1767	33.7	908	10.4	934	1413	8,543	$10.20	62.95	52.75
L, P–K, Super.	Chks	39.8	2237	41.3	1308	16.7	1557	2026	12,830	10.70	94.38	83.68
L, 2P–K, Rock	2	33.7	1975	33.8	1025	11.7	939	1775	9,855	9.80	73.21	63.41
L, N–½P–K, Super	3	34.8	1984	36.3	1125	14.4	1317	2074	10,955	13.08	80.85	67.78
L, N–P–K Super	4	39.6	2214	39.4	1199	17.4	1569	2443	12,505	15.96	92.70	76.74
L, N–1½P–½K Super	5	42.3	2291	42.1	1310	17.5	1818	2708	13,482	16.34	98.77	82.43
L, N–1½P–K, Super	7	43.7	2386	41.8	1367	20.4	2011	2922	14,285	18.84	104.69	85.85
L, N–1½P–1½K Super	8	45.5	2507	45.8	1502	22.0	2180	3235	15,394	21.34	112.57	91.23
L, N–2P–K	9	46.5	2543	46.3	1605	22.8	2190	3202	15,646	21.72	114.51	92.79
L, N–P–K, Bone	12	41.5	2330	42.0	1362	17.0	1591	2796	13,348	17.88	97.91	80.03
L, N–P–K, Slag	13	43.6	2433	45.8	1552	20.7	1977	3118	14,836	17.69	108.50	90.81
L, N–P–K, Rock	14	31.4	1968	36.4	1144	13.5	1245	1917	10,445	12.60	76.36	63.72
L, N–2P–K, Rock	15	33.0	2047	36.8	1121	13.5	1386	2126	10,980	15.00	79.65	64.65
L, N–3P–K, Rock	17	38.8	2192	41.9	1368	16.5	1641	2536	12,784	17.40	93.43	76.03
L, N–2P–K, Rock + Gypsum	19	39.1	2209	40.4	1373	18.9	1853	2323	12,607	21.36	91.89	70.53
L, N–2P–K, Rock + Sulphur	22	37.1	2263	39.0	1127	20.4	1783	2228	12,918	17.58	94.47	76.89
L, Manure	18	37.9	2198	42.2	1379	16.4	1654	2393	12,446	18.00	92.50	74.50
L, Manure + ½P, Super	23	41.9	2493	44.2	1457	22.1	2008	2848	14,474	20.88	107.07	86.19
L, Manure + P, Super	24	43.8	2568	44.9	1595	23.4	2092	3120	15,281	23.76	111.67	87.91
L, Manure + 1½P, Super	25	45.7	2668	45.8	1647	24.0	2106	3404	15,929	26.64	116.34	89.70
L, Manure + P, Super plowed under	27	47.9	2682	44.2	1503	25.5	2163	3012	15,658	23.76	116.00	92.24
L, Manure + 2 P, Rock harrowed in	28	43.8	2445	40.7	1262	20.8	1729	2684	13,734	22.80	102.35	79.55
L, Manure + 2 P, Rock	29	44.1	2398	41.9	1435	21.5	1864	2603	14,018	22.80	103.97	81.17
L, Manure + 3 P, Rock	30	43.8	2447	42.8	1310	20.6	1823	2,05	13,957	25.20	103.64	78.44
L, Manure + 4 P, Rock	32	46.5	2550	43.3	1319	21.5	1937	2847	14,582	27.60	108.23	80.63
L, Manure + P, Slag	33	50.4	2748	49.6	1634	24.5	2455	3342	16,764	25.49	122.69	97.20
L, Manure Accord. to crops grown + 2P, Rock *	34	51.1	2776	49.1	1493	21.7	1925	2938	15,580	19.38	116.03	96.65
Manure †	35	40.3	2309	41.3	1474	21.8	2024	2685	13,944	18.00	101.94	83.94
Manure + P, Super †	36	41.7	2248	40.7	1444	21.1	1966	2639	13,781	23.76	101.30	77.54
Manure + P, Slag †	38	41.4	2274	41.3	1379	21.7	1963	2745	13,883	25.49	102.59	77.10
Manure + 2P, Rock †	39	39.1	2076	42.6	1358	19.7	1825	2286	12,826	22.80	95.60	72.80

L=Ground limestone
N=20 lbs. nitrogen in nitrate of soda
P=48 lbs. phosphoric acid (P_2O_5)
K=50 lbs. potash (K_2O)

Manure=6 tons per acre
Super=16% superphosphate
Slag=Basic slag
Bone=Steamed bonemeal

Rock=Rock phosphate

† Yields on unlimed plots include one each of corn, oats and wheat on Tier II after these plots were limed by mistake in 1931. Where the effects of lime are given in Tables 7 and 8, the yield on this tier for 1931, 1932 and 1933 are omitted.

* On plot 34, 1¼ lbs. manure to average of 1 lb. of crops produced in 4 preceding years, omitting wheat grain. Average of 19 applications beginning 1924, 4.86 tons.

Oats grain, per bu.					.45				
Wheat grain, per bu.					.97				
Straw, per ton					5.00				
Hay, per ton					13.00				
Nitrate of soda	15.5%	N.,	per	ton	40.30,	per	lb.	N,	$.13
Superphosphate	16%	P_2O_5	"	"	19.20,	"	"	P_2O_5	.06
Rock phosphate	32%	P_2O_5	"	"	16.00,	"	"	P_2O_5	.025
Steamed bonemeal *	2.9% N. 24%	P_2O_5	"	"	46.00	"	"	P_2O_5	.08*
Basic slag	16%	P_2O_5	"	"	25.00,	"	"	P_2O_5	.078
Muriate of potash	50%	K_2O	"	"	50.00,	"	"	K_2O	.05
Gypsum, (land plaster)			"	"	15.00				
Flour of sulphur			"	"	40.00				
Manure			"	"	1.50				

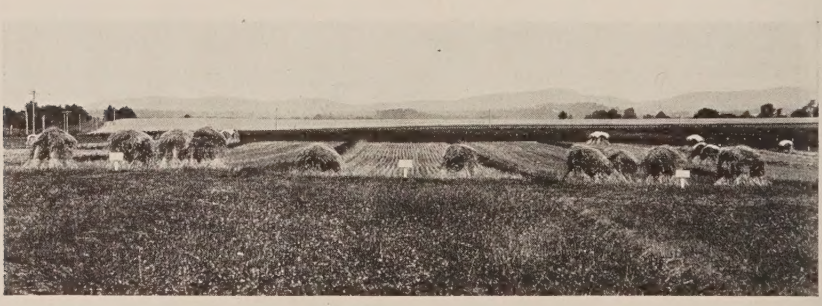
* To determine the cost of the phosphoric acid, nitrogen is assigned the same price as nitrogen in nitrate of soda.

DISCUSSION OF RESULTS

Differing Amounts of Phosphates.—Tables 2 to 5 give the results of using superphosphate and rock phosphate under different conditions. They indicate the importance of phosphoric acid in fertilizing this soil. Costs and net returns in these tables and those that follow are for one acre in a 4-year rotation, or the average for four acres a year. In all these comparisons, the greatest returns above the costs of the material were secured from the highest applications. Supplementing manure with superphosphate or rock phosphate has been very profitable. With the largest amounts used, superphosphate has increased the

TABLE 2. EFFECTS OF DIFFERENT AMOUNTS OF 16 PER CENT SUPERPHOSPHATE APPLIED WITH 130 POUNDS NITRATE OF SODA AND 100 POUNDS MURIATE OF POTASH

Rock phosphate	Average yields per acre								Value of all crops less cost of fertilizers
	Plot Nos.	Corn ears	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay	
		Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.	
None	10	26.0	1767	33.7	968	10.4	934	1413	$52.75
150 lbs.	3	34.8	1984	36.3	1125	14.4	1317	2074	67.78
300 lbs.	4	39.6	2214	39.4	1199	17.4	1569	2443	76.74
450 lbs.	7	43.7	2386	41.8	1367	20.4	2011	2922	85.85
600 lbs.	9	46.5	2543	46.3	1605	22.8	2190	3202	92.79



EFFECT OF SUPERPHOSPHATE ON YIELDS OF WHEAT IN 1930
Left to Right: Plot 9, N-2P-K, 28.3 bushels.
Plot 10, N- O-K, 13.9 bushels.
Plot 11, O- P-K, 23.8 bushels.

net returns $15.20 over manure alone, and rock phosphate $6.13. Manure is relatively low in phosphoric acid; the addition of superphosphate usually is a very profitable investment.

TABLE 3. EFFECTS OF DIFFERENT AMOUNTS OF 32 PER CENT ROCK PHOSPHATE APPLIED WITH 130 POUNDS NITRATE OF SODA AND 100 POUNDS MURIATE OF POTASH

Rock phosphate	Average yields per acre								Value of all crops less cost of fertilizers
	Plot Nos.	Corn ears	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay	
		Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.	
None	10	26.0	1767	33.7	908	10.4	934	1413	$52.75
150 lbs.	14	31.4	1968	36.4	1144	13.5	1245	1917	63.72
300 lbs.	15	33.0	2047	36.8	1121	13.5	1386	2126	64.65
450 lbs.	17	38.8	2192	41.9	1368	16.5	1641	2536	76.03

TABLE 4. EFFECTS OF DIFFERENT AMOUNTS OF SUPERPHOSPHATE APPLIED WITH SIX TONS OF MANURE

Superphosphate	Average yields per acre								Value of all crops less cost of fertilizers
	Plot Nos.	Corn ears	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay	
		Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.	
None	22	37.1	2263	39.0	1127	20.4	1783	2228	$74.50
150 lbs.	23	41.9	2493	44.2	1457	22.1	2008	2848	86.19
300 lbs.	24	43.8	2568	44.9	1595	23.4	2092	3120	87.91
450 lbs.	25	45.7	2668	45.8	1647	24.0	2106	3404	89.70

TABLE 5. EFFECTS OF DIFFERENT AMOUNTS OF 32 PER CENT ROCK PHOSPHATE APPLIED WITH SIX TONS OF MANURE

Rock phosphate	Average yields per acre								Value of all crops less cost of fertilizers
	Plot Nos.	Corn ears	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay	
		Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.	
None	22	37.1	2263	39.0	1127	20.4	1783	2228	$74.50
300 lbs.	29	44.1	2398	41.9	1435	21.5	1864	2603	81.17
450 lbs.	30	43.8	2447	42.8	1310	20.6	1823	2705	78.44
600 lbs.	32	46.5	2550	43.3	1319	21.5	1937	2847	80.63

Comparison of Phosphates.—Table 6 shows the relative merits of various phosphates when applied with other commercial fertilizers; Tables 7 and 8, when applied with manure. When only commercial fertilizer was used, basic slag led in yields and in net returns. It also led when used with manure on limed land. When used with other commercial fertilizers, bone-meal was next, then superphosphate, and rock phosphate last. When used with manure on unlimed land, slag

and superphosphate were practically equal in yields and net returns; both were superior to rock phosphate. The apparently high yields and net returns from slag on plots 13 and 33 (Tables 6 and 7) may be misleading, for in the preliminary period, before fertilizers were applied, plot 13 gave a higher yield than either plot 12 or plot 14; and plot 33, where there had been a blue-grass roadway, also gave relatively high yields.

On some soils, rock phosphate has done relatively better in comparison with superphosphate when the soil is acid than when it is alkaline.[2] For this reason, rock phosphate, basic slag, and superphosphate were compared on both limed and unlimed plots in this experiment each

[2] "The effects of liming on the availability of soil potassium, phosphorus and sulphur." J. K. Plummer, Jour. A. S. A., Vol. 13, pp. 162-171.
"Phosphate and limestone for Kentucky soils" University of Kentucky Cir. No. 123, by S. C. Jones and R. E. Stephenson.

TABLE 6. YIELDS FROM DIFFERENT CARRIERS OF PHOSPHORIC ACID APPLIED WITH 130 POUNDS NITRATE OF SODA AND 100 POUNDS MURIATE OF POTASH

Phosphate	Average yields per acre									Value of all crops less cost of fertilizers
	P_2O_5 Lbs.	Plot Nos.	Corn ears	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay	
			Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.	
None		10	26.0	1767	33.7	908	10.4	934	1413	$52.75
300 lbs. superphosphate	48	4	39.6	2214	39.4	1199	17.4	1569	2443	76.74
200 lbs. bone meal	48	12	41.5	2330	42.0	1362	17.0	1591	2790	80.03
300 lbs. basic slag	48	13	43.6	2433	45.8	1552	20.7	1977	3118	90.31
150 lbs. rock phosphate	48	14	31.4	1968	36.4	1144	13.5	1245	1917	63.72
300 lbs. rock phosphate	96	15	33.0	2047	36.8	1121	13.5	1386	2126	64.65
450 lbs. rock phosphate	144	17	38.8	2192	41.9	1268	16.5	1641	2536	76.08

TABLE 7. YIELDS FROM DIFFERENT CARRIERS OF PHOSPHORIC ACID APPLIED WITH SIX TONS OF MANURE ON LIMED LAND

Phosphate	P_2O_5 Lbs.	Average yields per acre								Value of all crops less cost of fertilizers
		Plot Nos.	Corn ears	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay	
			Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.	
None		22	37.1	2263	39.0	1127	20.4	1783	2228	$74.50
300 lbs. superphosphate	48	24	43.8	2568	44.9	1595	23.4	2092	3120	87.91
300 lbs. basic slag	48	33	50.4*	2748*	49.6*	1634*	24.5*	2455*	3342*	97.20*
300 lbs. rock phosphate	96	29	44.1	2398	41.9	1435	21.5	1864	2603	81.17
450 lbs rock phosphate	144	30	43.8	2447	42.8	1310	20.6	1823	2705	78.44

* Plot 33 is located were there had been a blue grass service road before the plots were laid out; in the preliminary period, it gave relatively high yields.

applied at the rate of 300 pounds per acre. Comparing the average total yields per rotation, on the limed land rock phosphate gave 91.7 per cent as much yield as superphosphate; on the unlimed land, 93.1 per cent. This difference probably is not significant.

TABLE 8. YIELDS FROM DIFFERENT CARRIERS OF PHOSPHORIC ACID APPLIED WITH SIX TONS OF MANURE ON UNLIMED LAND*

Phosphate	P_2O_5 Lbs.	Average yields per acre								Value of all crops less cost of fertilizers
		Plot Nos.	Corn ears	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay	
			Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.	
300 lbs. superphosphate	48	36	40.8	2235	41.6	1485	19.8	1832	2639	$75.77
300 lbs. basic slag	48	38	40.3	2248	42.1	1410	21.8	1827	2745	76.42
300 lbs. rock phosphate	96	39	36.4	2038	40.1	1379	20.1	1684	2286	70.69

* By mistake, the manured plots which were to have been left unlimed were limed on one tier before planting to corn in 1931. The crops on this tier after liming are omitted.

TABLE 9. A COMPARISON OF TOTAL YIELDS PER ROTATION FROM SUPERPHOSPHATE AND ROCK PHOSPHATE IN THE THREE ROTATIONS

With nitrate of soda and muriate of potash on limed land

Phosphate	P_2O_5 Lbs.	Plot Nos.	1922–25		1926–29		1930–33	
			Yields Lbs.	Relative	Yields Lbs.	Relative	Yields Lbs.	Relative
300 lbs superphosphate	48	4	13,511	100	11,782	100	12,238	100
150 lbs rock phosphate	48	14	11,558	86	10,058	85	9,736	80
300 lbs. rock phosphate	96	15	11,593	86	10,630	90	10,698	87
450 lbs. rock phosphate	144	17	13,659	101	11,834	100	12,854	105

With six tons of manure on limed land

Phosphate	P_2O_5 Lbs.	Plot Nos.	1922–25		1926–29		1930–33	
			Yields Lbs.	Relative	Yields Lbs.	Relative	Yields Lbs.	Relative
300 lbs. superphosphate	48	24	15,943	100	14,236	100	15,895	100
300 lbs. rock phosphate	96	29	14,655	92	13,042	92	14,343	90
450 lbs. rock phosphate	144	30	14,702	92	13,174	93	14,002	88
600 lbs. rock phosphate	192	32	14,927	94	13,951	99	14,882	94

With six tons of manure on unlimed land

Phosphate	P_2O_5 Lbs.	Plot Nos.	1922–25		1926–29		1930–33	
			Yields Lbs.	Relative	Yields Lbs.	Relative	Yields Lbs.	Relative
300 lbs. superphosphate	48	36	14,372	100	12,597	100	13,819	100
300 lbs. rock phosphate	96	39	12,988	90	11,878	94	12,438	90

Superphosphate and Rock Phosphate Compared.—In order to ascertain whether rock phosphate has given relatively larger yields as the experiment has progressed, Table 9 gives a comparison of total yields per rotation from superphosphate and rock phosphate for the three rotations separately. There are irregularities and inconsistencies, perhaps due to errors in field plot work, but in only 2 of the 8 comparisons has there been a greater yield in the last four years than in the first four.

Gypsum and Sulphur.—When this experiment was planned it was suggested that this soil may need sulphur, which is supplied in the form of gypsum in superphosphate but which is largely lacking in rock phosphate; hence it was planned to add as much gypsum on plot 18 as would have been supplied if the phosphoric acid had been applied as superphosphate, and to apply to plot 19 the equivalent of sulphur, as flour of sulphur. The applications have averaged 424 pounds of gypsum and 64.5 pounds of sulphur respectively. Both materials have increased yields (Table 10), either because they supply a sulphur deficiency or because they make the phosphoric acid in the rock phosphate more available, or both.

Different Amounts of Potash.—The results of applying different amounts of potash are given in Table 11. As in some other comparisons, there is an inconsistency in that the last increment apparently

TABLE 10. THE EFFECT ON YIELDS OF ADDING GYPSUM AND FLOUR OF SULPHUR TOGETHER WITH 300 POUNDS OF ROCK PHOSPHATE, ON PLOTS RECEIVING 130 POUNDS OF NITRATE OF SODA AND 100 POUNDS OF MURIATE OF POTASH ALSO

Phosphate	Plot Nos.	Average yields per acre							Value of all crops less cost of fertilizers
		Corn ears Bu.	Corn stover Lbs.	Oats grain Bu.	Oats straw Lbs.	Wheat grain Bu.	Wheat straw Lbs.	Hay Lbs.	
300 lbs. rock phosphate	15	33.0	2047	36.8	1121	13.5	1386	2126	$64.65
300 lbs. rock phosphate + gypsum	18	37.9	2198	42.2	1379	16.4	1654	2393	70.53
300 lbs. rock phosphate + sulphur	19	39.1	2209	40.4	1373	18.9	1853	2323	76.89
300 lbs. superphosphate	4	39.6	2214	39.4	1199	17.4	1569	2443	76.74

TABLE 11. YIELDS FROM DIFFERENT AMOUNTS OF MURIATE OF POTASH APPLIED WITH 130 POUNDS OF NITRATE OF SODA AND 450 POUNDS OF SUPERPHOSPHATE

Muriate of potash	Plot Nos.	Average yields per acre							Value of all crops less cost of fertilizers
		Corn ears Bu.	Corn stover Lbs.	Oats grain Bu.	Oats straw Lbs.	Wheat grain Bu.	Wheat straw Lbs.	Hay Lbs.	
50 Lbs.	5	42.3	2291	42.1	1310	17.5	1818	2708	$82.43
100 Lbs.	7	43.7	2386	41.8	1367	20.4	2011	2922	85.85
150 Lbs.	8	45.5	2507	45.8	1502	22.0	2180	3235	91.23

gave a greater return than the second. It would seem that even a larger amount than 150 pounds per acre could be used profitably. Unfortunately, there is no plot receiving nitrate of soda and superphosphate only.

Effect of Nitrogen on Yields.—Nitrogen has been applied at only one rate, 20 pounds per acre, which is contained in approximately 130 pounds of nitrate of soda. This has been applied in addition to superphosphate and muriate of potash, and also to rock phosphate and muriate of potash. These results indicate a net loss from nitrogen on plot 4 and a slight gain on plot 15 (Table 12).

Method of Applying Phosphate.—As a rule, superphosphate has been applied just before planting corn or sowing wheat and harrowed into the soil, while rock phosphate has been applied before plowing. On plots 27 and 28 these methods were reversed. The average yields per rotation are slightly greater for both phosphates when plowed down than when harrowed in, but the differences are hardly significant (Table 13).

Value of Manure.—In livestock farming, manure produced on the farm constitutes the greater part of the plant food added to the soil. Though it is unusual for a general farmer to purchase manure, it is interesting to see what manure has been worth, under the conditions of this test, where six tons have been applied per acre for corn and six tons for wheat. In computing net returns above the cost of the treatments, manure has been assigned a value of $1.50 per ton. At this price manure alone has not been nearly as profitable as applications of superphosphate and muriate of potash, or of complete commercial fertilizer which has included 450 to 600 pounds of superphosphate (Table 14). Adding superphosphate to the manured plots has greatly increased the net returns, so that these plots compare favorably with the best commercial fertilizer plots.

TABLE 12. RESULTS FROM ADDING 130 POUNDS NITRATE OF SODA TO 300 POUNDS SUPERPHOSPHATE AND 100 POUNDS MURIATE OF POTASH; AND TO 300 POUNDS ROCK PHOSPHATE AND 100 POUNDS MURIATE OF POTASH

Treatment	Plot Nos.	Average yields per acre							Value of all crops less cost of fertilizers
		Corn ears Bu.	Corn stover Lbs.	Oats grain Bu.	Oats straw Lbs.	Wheat grain Bu.	Wheat straw Lbs.	Hay Lbs.	
Superphosphate and potash	Check	39.8	2237	41.3	1308	16.7	1557	2026	$83.68
Nitrate, superphosphate, and potash	4	39.6	2214	39.4	1199	17.4	1569	2443	76.74
Rock phosphate and potash	2	33.7	1975	33.8	1025	11.7	989	1775	68.41
Nitrate, rock phosphate and potash	15	33.0	2047	36.8	1121	13.5	1386	2126	64.65

TABLE 13. COMPARISON OF METHODS OF APPLYING SUPERPHOSPHATE AND ROCK PHOSPHATE ON PLOTS RECEIVING SIX TONS OF MANURE PER ACRE

Phosphate	Plot Nos.	Average yields per acre							Value of all crops less cost of fertilizers
		Corn ears Bu.	Corn stover Lbs.	Oats grain Bu.	Oats straw Lbs.	Wheat grain Bu.	Wheat straw Lbs.	Hay Lbs.	
300 lbs. superphosphate plowed down	27	47.9	2682	44.2	1503	25.5	2163	3012	$92.24
300 lbs. superphosphate harrowed in	24	43.8	2568	44.9	1595	23.4	2092	3120	87.91
300 lbs. rock phosphate plowed down	29	44.1	2398	41.9	1435	21.5	1864	2603	81.17
300 lbs. rock phosphate harrowed in	28	43.8	2445	40.7	1262	20.8	1729	2684	79.55

The importance of supplementing manure with superphosphate is brought out clearly in Table 15. The increase in value of crops per ton of manure used was $2.90 where manure was used alone, but after paying for the superphosphate supplement, the returns per ton of manure increased to $3.87, $3.98, and $4.17 per ton respectively, with the different amounts of superphosphate used. In a rotation, the plot receiving the most superphosphate as an addition to manure returned a profit of $15.20 more than the plot which received manure alone.

In the rare cases where manure can be purchased, what could be paid for it to give as good a profit as may be secured with commercial fertilizer alone? Yields, in a good rotation, can be maintained without manure. Obviously the price that can be paid will vary with the prices of farm products and of commercial fertilizers. With the prices here given (pages 4 and 6) and under the conditions of this test, the following results show what could be paid for manure.

On plot 9, the most profitable commercial fertilizer plot, the net return above the cost of fertilizer was $92.79, which was $35.09 greater

TABLE 14. COMPARISON OF CERTAIN COMMERCIAL FERTILIZER PLOTS WITH CERTAIN MANURED PLOTS; ALL PLOTS LIMED AND THE PHOSPHORIC ACID SUPPLIED IN 16 PER CENT SUPERPHOSPHATE

Treatment *	Plot Nos.	Average yields per acre							Value of all crops less cost of fertilizers
		Corn ears Bu.	Corn stover Lbs.	Oats grain Bu.	Oats straw Lbs.	Wheat grain Bu.	Wheat straw Lbs.	Hay Lbs.	
P-K	Chks	39.8	2237	41.3	1308	16.7	1557	2026	$83.68
N-P-K	4	39.6	2214	39.4	1199	17.4	1569	2443	76.74
N-1½P-K	7	43.7	2386	41.8	1367	20.4	2011	2922	85.85
N 2P-K	9	46.5	2543	46.3	1605	22.8	2190	3202	92.79
Manure	22	37.1	2263	39.0	1127	20.4	1783	2228	74.50
Manure + P	24	43.8	2568	44.9	1595	23.4	2092	3120	87.91
Manure + 1½P	25	45.7	2668	45.8	1647	24.0	2106	3404	89.70

* N=20 Lbs. Nitrogen, 130 lbs. nitrate of soda.
P=48 Lbs. Phosphoric acid, 300 lbs. 16 per cent superphosphate.
K=50 Lbs. Potash, 100 lbs. 50 per cent muriate.

than the value of the crops on the unfertilized plots. Plot 25, the most profitable manured plot, has yielded crops worth $58.64 more than plots where no fertilizer was used. The superphosphate applied to this plot cost $8.64, leaving $50 as the cost of the manure, and the profit. To give as much profit as was secured from Plot 9, $35.09, the manure could not cost over $50.00 less $35.09, or $14.91. This is for 12 tons, the amount used in a rotation. The price per ton, therefore, could be $1.24.

TABLE 15. VALUE OF INCREASES IN CROP YIELDS ON MANURED PLOTS LESS COST OF SUPERPHOSPHATE APPLIED ON THE SAME PLOTS

Treatments per application	Plot Nos.	Value of crops in a rotation	Cost of superphosphate	Value of increase less cost of superphosphate	Value of net increase per ton of manure
Nothing	20,40	$57.70			
6 Tons manure	22	92.50		$34.80	$2.90
6 Tons manure and 150 lbs. superphosphate	23	107.07	$2.88	46.49	3.87
6 Tons manure and 300 lbs. superphosphate	24	111.16	5.76	47.70	3.98
6 Tons manure and 450 lbs. superphosphate	25	116.34	8.64	50.00	4.17

SUMMARY

This bulletin summarizes the yields secured in a fertilizer test on Hagerstown silt loam over a period of 12 years. The rotation is corn, oats, wheat, and mixed clover and timothy hay, each one year, and the fertilizers are applied to the corn and to the wheat.

On this soil, phosphorus is the limiting element. Where it was omitted, applications of nitrate of soda and muriate of potash gave little increase in yields. When phosphorus was applied with nitrogen and potash the heaviest applications of 16 per cent superphosphate and 32 per cent rock phosphate, 450 and 600 pounds respectively, gave the largest yields and the highest net returns. When applied with six tons of manure also, the largest profits were realized from these high applications.

Basic slag, bone-meal, superphosphate, and rock phosphate were compared when applied at rates equivalent to 300 pounds of 16 per cent superphosphate, with nitrate of soda and muriate of potash added. The comparative yields were in the order given. These phosphates, with the exception of bone-meal, also have been applied with six tons of manure. On limed land, the rank in yield was basic slag, superphosphate, and rock phosphate. Applied with manure on unlimed land, basic slag did not give significantly higher yields than superphosphate. The relative yields from rock phosphate were not significantly higher on unlimed land than on limed.

As compared with superphosphate, the rock phosphate plots were not more productive as the experiment progressed.

Both gypsum and flour of sulphur increased the yields from the rock

phosphate plots when they were applied with nitrate of soda and muriate of potash.

Twenty pounds of nitrogen in nitrate of soda (equivalent to approximately 130 pounds of nitrate) applied with superphosphate and muriate of potash apparently increased the yields of wheat slightly, but not the yields of corn.

Where muriate of potash was applied with the other commercial fertilizers, 150 pounds gave larger yields and higher net returns than 50 pounds or 100 pounds.

The difference in results from plowing down rock phosphate or superphosphate, as compared with applying them on the surface of plowed ground and harrowing them in, was hardly significant.

The importance of supplementing manure with a phosphate is shown very clearly. At the prices used in this bulletin, when 150 pounds of 16 per cent superphosphate were applied in addition to manure, the return per ton of manure above the extra cost of the superphosphate was 97 cents more than where manure alone was applied. Increasing the superphosphate to 300 pounds and 450 pounds increased the net returns per ton of manure to $1.08 and to $1.27 respectively.